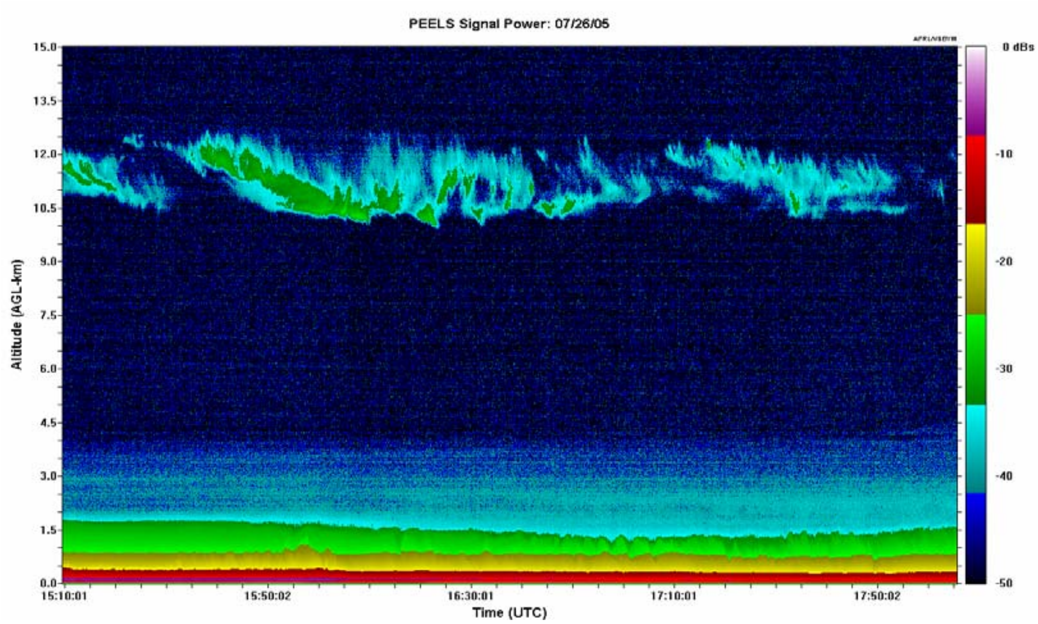
Air Force Research Laboratory | AFRL

High Altitude Lasers and Cirrus Clouds

Success Story: AFRL Technology Milestones

AFRL scientists recently completed a project to study the potential impacts of cirrus clouds on airborne defensive laser systems. Such systems are envisioned for missile defense, and are expected to engage theater ballistic missiles during their boost phase. High energy lasers are subject to optical turbulence that may diffract the beam, causing beam spreading and reducing power on the target. Another atmospheric effect is the absorption and scattering of laser light by ice crystals in cirrus clouds. The recent AFRL study quantified the effects that observed cirrus layers might have on laser transmission from a high altitude laser source.



Signal power as a function of altitude as measured by near-zenith pointing 1.574 micrometers (µm) lidar at Hanscom AFB, Mass., during the period 1510 – 1805 hours Coordinated Universal Time (UTC), 26 July 2005, showing a cirrus cloud layer between 10 and 12.5 kilometers above ground level.

Scientists conducted an 11-month field campaign at Hanscom AFB, Mass., in 2005 to collect measurements of cirrus clouds. Ground-based cloud profiling radar and light detection and ranging (lidar), radiosondes, satellite imagery and a surface observer collected data in 26 three-hour cirrus episodes that occurred from February to December. Radar/lidar data specified the top and base altitude of the cirrus layer, and satellite data provided an estimate of effective ice particle size and ice water content. The research team found that radiosonde relative humidity soundings must supplement satellite imagery to insure accurate top and base height estimates, in reference to radar/lidar measurements. In addition, radiosondes can infer the presence of very thin cirrus layers undetected by the satellite. Scientists also used the cirrus altitudes and crystal properties in laser transmission models. They computed the transmittance, or fraction of initial laser power, incident on a hypothetical missile as a function of ascent altitude. Results showed a transmittance of 0.1-0.2 at the base of the cirrus cloud for a series of scenarios of an above-cloud source and a target launched at varying horizontal separation distances. Extinction of the laser beam was significant as it passed through the cirrus layer, and distances of more than 50 kilometers resulted in transmittances of less than 0.1.

These results indicate that cirrus clouds can have a profound impact on a propagating laser beam. This study suggests that passing through even thin cirrus will result in a reduction of power. State of the art radiosondes can detect the presence and altitude of cirrus layers of varying optical thickness. When complemented by satellite imagery to indicate aerial coverage, the radiosonde can provide critical support to field tests of a high altitude laser system to aid in avoiding cirrus clouds. This will greatly reduce the cost of cirrus detection over expensive shipment and operation of ground-based radars and lidars.